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(54) **TRANSMISSION ARRANGEMENT FOR A VEHICLE**

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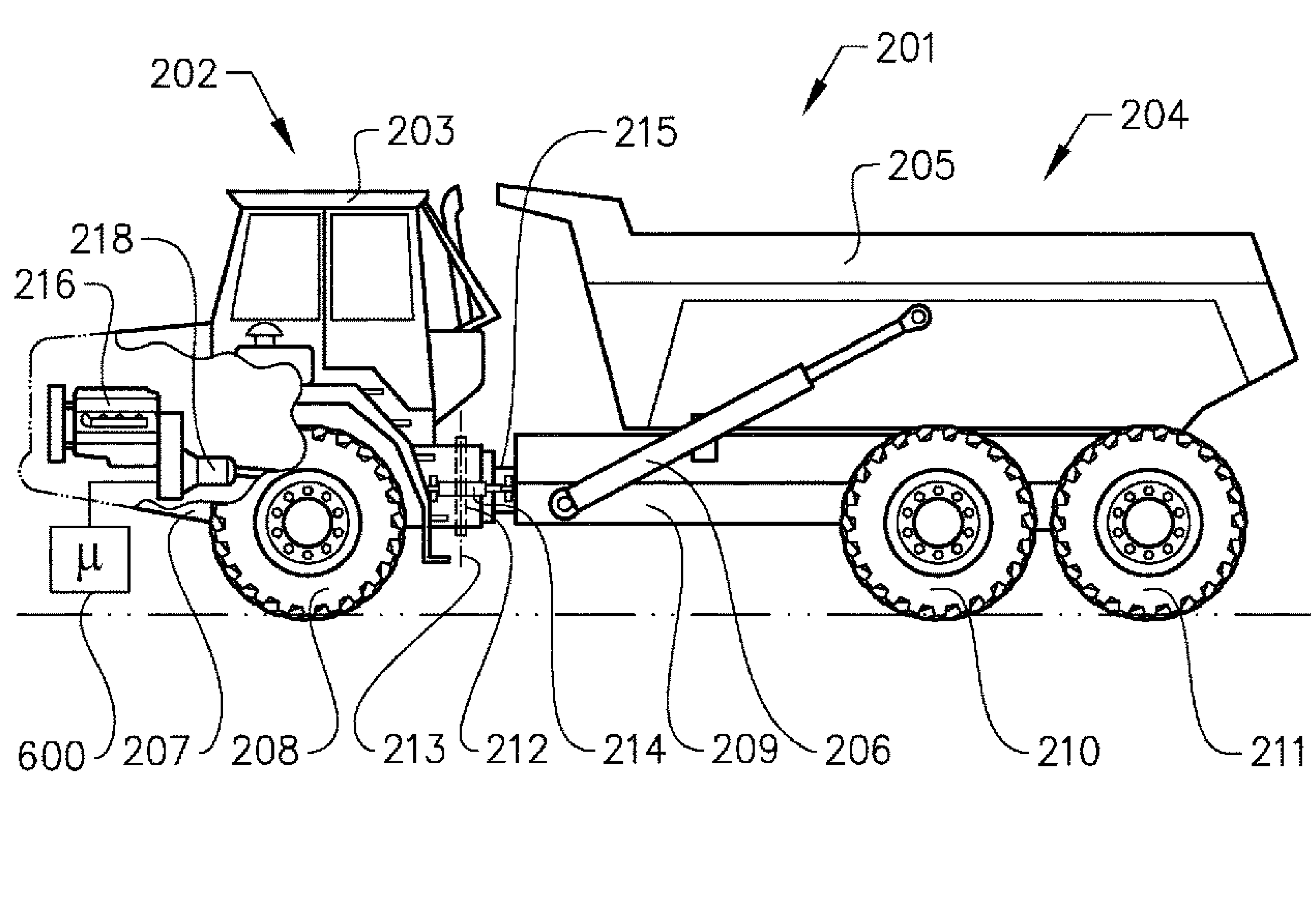
(57) **ABSTRACT**

A transmission arrangement for a vehicle includes a first, a second, a third, and a fourth planetary gear set including a sun gear, a planet carrier and a ring gear, respectively, wherein the transmission arrangement further includes a transmission housing, an input shaft and an output shaft, wherein the ring gear of the first planetary gear set and the input shaft are operatively connected to each other; the sun gear of the first planetary gear set, and the sun gear of the second planetary gear set are operatively connected to each other; the planet carrier of the second planetary gear set and the ring gear of the third planetary gear set are operatively connected to each other; the planet carrier of the third planetary gear set is operatively connected to the transmission housing; the sun gear of the third planetary gear set and the sun gear of the fourth planetary gear set are operatively connected to each other; and the planet carrier of the fourth planetary gear set and the output shaft are operatively connected to each other.

14 Claims, 1 Drawing Sheet



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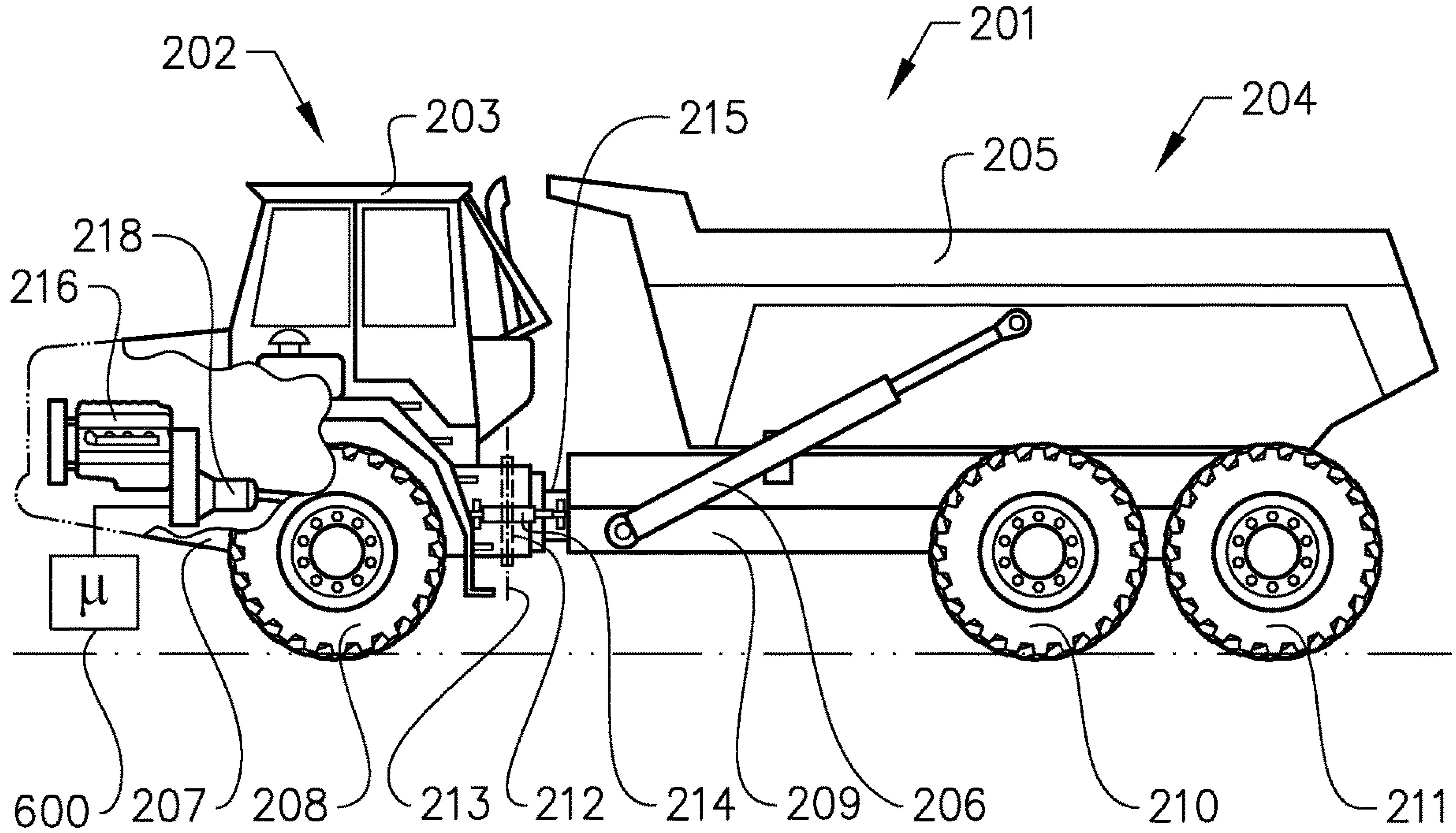
201
202
203
215
204
205
218
216
μ
600
207
208
213
212
214
209
206
210
211

FIG. 1

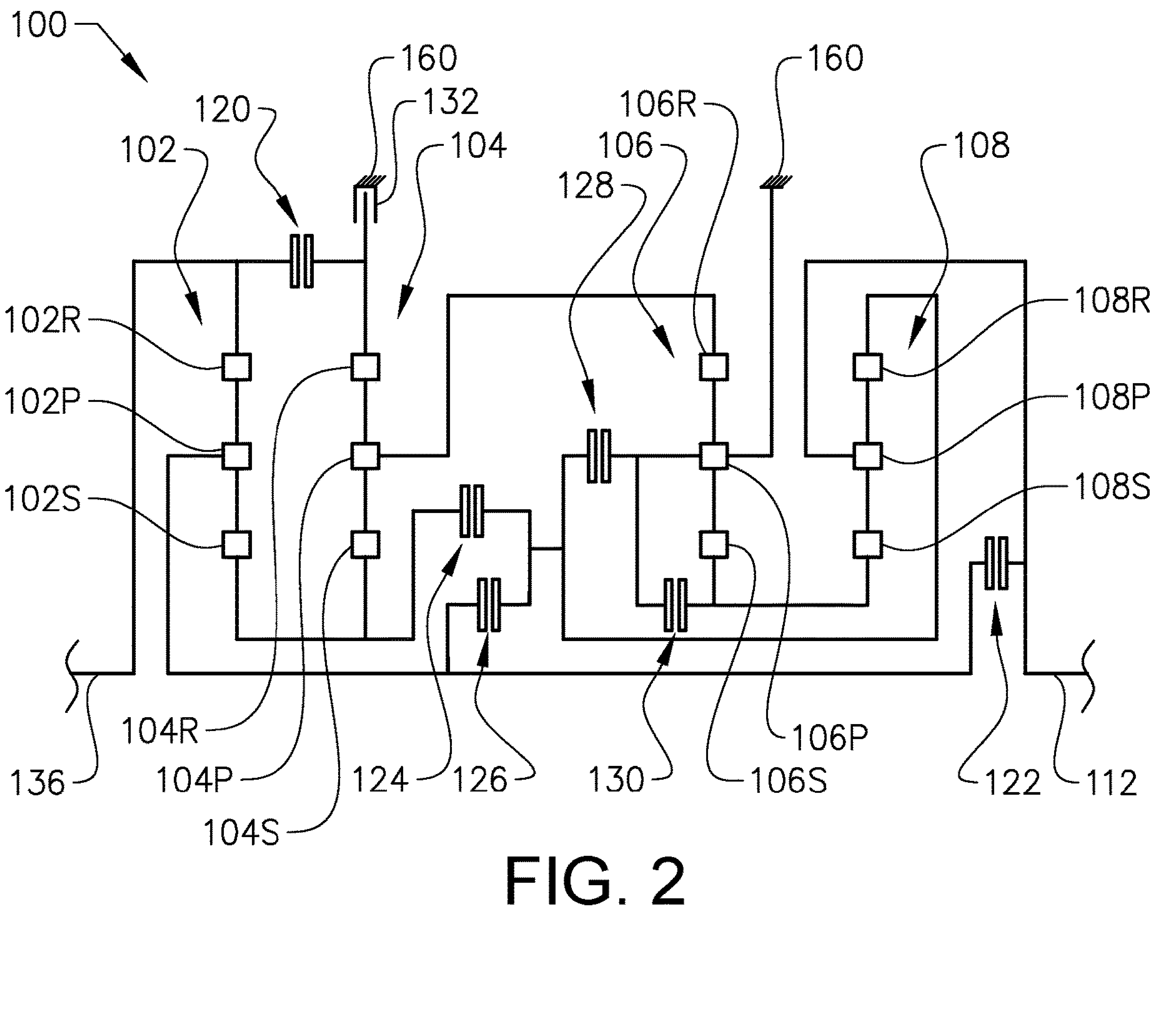
100
160
132
160
120
104
106R
102
106
108
128
102R
108R
102P
108P
102S
108S
104R
106P
136
104P
124
126
130
106S
122
112
104S

FIG. 2

TRANSMISSION ARRANGEMENT FOR A VEHICLE

BACKGROUND AND SUMMARY

The present invention relates to a transmission arrangement for a vehicle. The invention also relates to a vehicle comprising such a transmission arrangement. The invention is applicable on vehicles, in particularly working machines such as e.g. wheel loaders, articulated haulers, dump trucks, etc. Although the invention will mainly be described in relation to an articulated hauler, it may also be applicable for other types of vehicles such as e.g. trucks.

In connection with transportation of heavy loads at construction sites or the like, a working machine is often used. The working machines may be utilized for transportations in connection with road or tunnel building, sand pits, mines, forestry and similar environments. Thus, the working machine is frequently operated with large and heavy loads in rough terrain and on slippery ground where no regular roads are present.

In order to fulfil the desired demands from the fields where the working machine is frequently operated, high performance of the vehicle gearbox is necessary. The gearbox is arranged for adjusting the speed and tractive effort of the vehicle in dependency of the specific driving scenario. The gearbox comprises a transmission arrangement and depending on the specific type of gearbox, the transmission arrangement may comprise e.g. ordinary gear sets with cylindrical gear wheels in meshed connection with each other or planetary gear sets comprising a respective sun gear, ring gear and a planet carrier, or a combination of ordinary gear sets and one or more planetary gear sets.

SE 527 108 describes a vehicle transmission arrangement, particularly suitable for working machines. The transmission arrangement in SE 527 108 comprises an input shaft and an output shaft. Five planetary gear sets are arranged between the input shaft and the output shaft for providing the desired gear ratios. Also, the transmission arrangement comprises three clutches and five brakes for achieving the desired gear shifts. Hereby, nine forward gears and four reverse gears are provided for the transmission arrangement in. SE 527 108.

Although the transmission arrangement in SE 527 108 provides for a sufficient number of gears, the transmission arrangement is still in need of further improvements in terms of costs and functionality.

It is desirable to provide a transmission arrangement that enables fewer components to be used and has an improved gear shiftability in comparison to the prior art.

According to a first aspect of the present invention, there is provided a transmission arrangement for a vehicle, the transmission arrangement comprising a first, a second, a third, and a fourth planetary gear set comprising a sun gear, a planet carrier and a ring gear, respectively, wherein the transmission arrangement further comprises a transmission lousing an input shaft and an output shaft, wherein the ring gear of the first planetary gear set and the input shaft are operatively connected to each other; the sun gear of the first planetary gear set and the sun gear of the second planetary gear set are operatively connected to each other; the planet carrier of the second planetary gear set and the ring gear of the third planetary gear set are operatively connected to each other; the planet carrier of the third planetary gear set is operatively connected to the transmission housing, the sun gear of the third planetary gear set and the sun gear of the fourth planetary gear set are operatively connected to each other; and the planet carrier of the fourth planetary gear set and the output shaft are operatively connected to each other.

The wording "operatively connected to" should in the following and throughout the entire description be interpreted such that the components thereof are fixedly connected to each other, i.e. the rotational speeds of the components which are operatively connected to each other are equal. Hence, no engagement and disengagement mechanism or the like is arranged between the components that are operatively connected to each other and they can therefore not be disengaged from one another during operation. Accordingly, the planet carrier of the fourth planetary gear set is always connected to the output shaft of the transmission arrangement.

An advantage of the present invention is that, in comparison to the prior an, only four planetary gear sets are used in order to obtain a sufficient number of forward and reverse gears. This is advantageous both in terms of cost and packaging of the transmission arrangement since the number of components reduces the total cost for the transmission arrangement at the same time as it will be easier to fit the transmission arrangement to a vehicle. The engine compartment is an environment where it often is desirable to reduce the size of the components housed therein and the present invention hence reduces the size of the transmission arrangement by having one less planetary gear set in comparison to the prior art.

Moreover, by means of the present invention, nine forward gears and three reverse gears are obtainable, where the ratios and the steps for the different gears are considered to be able to appropriately operate e.g. a working machine to provide sufficient speed when necessary and sufficient torque when necessary. The ratio and step for the different obtainable gears will be described further below in relation to the detailed description of the present invention.

A still further advantage is that further additional gears and alternative gears in addition to the nine forward gears and the three reverse gears described above are obtainable. These additional gears and alternative gears will also be described further below in relation to the detailed description of the present invention.

According to an example embodiment, the transmission arrangement may comprise a first connecting mechanism for selectively connecting the ring gear of the second planetary gear set to the ring gear of the first planetary gear set and to the input shaft. The first connecting mechanism may, for example, be a clutch arrangement, such as e.g. a wet or dry friction disc clutch. Other alternatives are also conceivable, such as a dog clutch.

The wording "selectively connectable to" should be understood to mean that the components thereof are connectable to each other such that, when being connected to each other, the components have equal rotational speeds. Hence, the components may be directly connectable to each other or via another component.

According to an example embodiment, the transmission arrangement may comprise a second connecting mechanism for selectively connecting the planet carrier of the first planetary gear set to the output shaft and to the planet carrier of the fourth planetary gear set. The second connecting mechanism may, for example, be a clutch arrangement, such as e.g. a wet or dry friction disc clutch. Other alternatives are of course also conceivable.

According to an example embodiment, the transmission arrangement may comprise a third connecting mechanism for selectively connecting the ring, gear of the fourth planetary gear set to the sun gear of the first planetary gear set and to the sun gear of the second planetary gear set. The third connecting mechanism may, for example, be a clutch arrangement, such as e.g. a wet or dry friction disc clutch. Other alternatives are of course also conceivable.

According to an example embodiment, the transmission arrangement may comprise a fourth connecting mechanism for selectively connecting the planet carrier of the first planetary gear set to the ring gear of the fourth planetary gear set. The fourth connecting mechanism may, fir example, be a clutch arrangement, such as e.g. a wet or dry friction disc clutch. Other alternatives are of course also conceivable.

According to an example embodiment, the transmission arrangement may comprise a first locking mechanism for selectively locking the ring gear of the fourth planetary gear set to the transmission housing. The first locking mechanism may, or example, be a brake arrangement, such as e.g. a wet or dry friction disc brake. Other alternatives are also conceivable such as a dog clutch.

According to an example embodiment, the ring gear of the fourth planetary gear set may be selectively connectable to the transmission housing via the planet carrier of the third planetary gear set.

Accordingly, since the planet carrier of the third planetary gear set is operatively connected to the transmission housing, the ring gear of the fourth planetary gear set can hence be locked to the transmission housing via the planet carrier of the third planetary gear set such that the ring gear of the fourth planetary gear set is prevented from rotating.

According to an example embodiment, the transmission arrangement may comprise a second locking mechanism for selectively locking the sun gear of the third planetary gear set and the sun gear of the fourth planetary gear set to the transmission housing. The second locking mechanism may, for example, be a brake arrangement, such as e.g. a wet or dry friction disc brake. Other alternatives are of course also conceivable.

According to an example embodiment, the sun gear of the third planetary gear set and the sun gear of the fourth planetary gear set may be selectively connectable to the transmission housing via the planet carrier of the third planetary gear set.

Accordingly, since the planet carrier of the third planetary gear set is operatively connected to the transmission housing, the sun gear of the third planetary gear set and the sun gear of the fourth planetary gear set can hence be locked to the planet carrier of the third planetary gear set fin: preventing rotation of the sun gear of the third planetary gear set and the sun gear of the fourth planetary gear set.

According to an example embodiment, the transmission arrangement may comprise a third locking mechanism for selectively locking the ring gear of the second planetary gear set to the transmission housing. The third locking mechanism may, for example, be a brake arrangement, such as e.g. a wet or dry friction disc brake. Other alternatives are of course also conceivable.

Hereby, the ring gear of the second planetary gear set can hence be locked to the transmission housing such that the ring gear is prevented from rotating.

According to an example embodiment, the stationary gear ratio of each one of the first, second, third and fourth planetary gear sets may be negative. An advantage is that single planet wheels are used, which reduces cost and gear mesh losses.

According to a second aspect of the present invention there is provided a method for controlling a transmission arrangement, the transmission arrangement comprising a first, a second, a third, and a fourth planetary gear set comprising a sun gear, a planet carrier and a ring gear, respectively, wherein the transmission arrangement further comprises a transmission housing, an input shaft and an output shaft; the ring gear of the first planetary gear set being operatively connected to the input shaft; the sun gear of the first planetary'gear set being operatively connected to the sun gear of the second planetary gear set; the planet carrier of the second planetary gear set being operatively connected to the ring gear of the third planetary gear set; the planet carrier of the third planetary gear set being operatively connected to the transmission housing; the sun gear of the third planetary gear set being operatively connected to the sun gear of the fourth planetary gear set; the planet carrier of the fourth planetary gear set being operatively connected to the output shaft, wherein the transmission arrangement further comprises: a first connecting mechanism for selectively connecting the ring gear of the second planetary gear set to the ring gear of the first planetary gear set and to the input shaft; a second connecting mechanism for selectively connecting the planet carrier of the first planetary gear set to the output shaft and to the planet carrier of the fourth planetary gear set; a third connecting mechanism for selectively connecting the ring gear of the fourth planetary gear set to the sun gear of the first planetary gear set and to the sun gear of the second planetary gear set; a fourth connecting mechanism for selectively connecting the planet carrier of the first planetary gear set to the ring gear of the fourth planetary gear set, a first locking mechanism for selectively locking the ring gear of the fourth planetary gear set to the transmission housing; a second locking mechanism for selectively locking the sun gear of the third planetary gear set and the sun gear of the fourth planetary gear set to the transmission housing; and a third locking mechanism for selectively locking the ring gear of the second planetary gear set to the transmission housing, wherein fear at least one of the gears of the transmission arrangement, the method comprises the steps of: positioning three of the locking and connecting mechanisms in an engaged state; and positioning four of the locking and connecting mechanisms in a disengaged state.

Hereby, the majority of elements are disengaged for the different gears of the transmission arrangement, which thus may increase durability of friction components etc.

According to an example embodiment, the method may comprise the step of positioning the first and the third locking mechanisms, and the second connecting mechanism in an engaged state when engaging a first forward gear. According to an example embodiment, the method may comprise the step of positioning the first and the third locking mechanisms, and the fourth connecting mechanism in an engaged state when engaging a second forward gear. According to an example embodiment, the method may comprise the step of positioning the third locking mechanism, and the second and the fourth connecting mechanisms in an engaged state when engaging a third forward gear. According to an example embodiment, the method may comprise the step of positioning the second and the third locking mechanisms, and the fourth connecting mechanism in an engaged state when engaging a fourth forward gear. According to an example embodiment, the method may comprise the step of positioning the third locking mechanism, and the third and the fourth connecting mechanisms in an engaged state when engaging a fifth forward gear. According to an example embodiment, the method may comprise the step of positioning the second locking mechanism, and the third and the fourth connecting mechanisms in an engaged state when engaging a sixth forward gear. According to an example embodiment, the method may comprise the step of positioning the second, the third and the fourth connecting mechanisms in an engaged state when engaging a seventh forward gear. According to an example embodiment, the method may comprise the step of positioning the second locking mechanism, and the second and the third connecting mechanisms in an engaged, state when engaging an eighth forward gear. According to an example embodiment, the method may comprise the step of positioning the third locking mechanism, and the second and the third connecting mechanisms in an engaged state when engaging a ninth forward gear.

Thus, well defined forward gears are provided for the transmission arrangement.

According to an example embodiment, the method may comprise the step of positioning the first locking mechanism, and the first and the second connecting mechanisms in an engaged state when engaging a first reverse gear; According to an example embodiment, the method may comprise the step of positioning the first locking mechanism, and the first and the fourth connecting mechanisms in an engaged state when engaging a second reverse gear. According to an example embodiment, the method may comprise the step of positioning the first locking mechanism, and the first and the third connecting mechanisms in an engaged state when engaging a third reverse gear.

Thus, well defined reverse gears are provided for the transmission arrangement. All one-step gear shifts as well as all two-step gear shifts for the forward gears and the reverse gears are performed by only shifting one of the connecting and locking mechanisms from an engaged state to a disengaged state, and only shifting one of the connecting and locking mechanisms from a disengaged state to an engaged state.

According to an example embodiment, the method may comprise the step of positioning the second and the third locking mechanisms, and the second connecting mechanism in an engaged state when engaging a first additional forward gear having a gear ratio between the gear ratios of the fifth and the sixth forward gears.

Hereby, a further gear is arranged between the fifth and sixth forward gears which provides for an additional step between the fifth and sixth gears. A gear shift can be executed from the fourth forward gear to the first additional forward gear. This will provide for a smaller step in comparison to a gear shift from the fourth forward gear to the sixth forward gear. Further, when executing a gear shift from the fourth forward gear to the first additional forward gear only one of the connecting and locking mechanisms are changed from an engaged state to a disengaged state, and only one of the connecting and locking mechanisms are changed from a disengaged state to an engaged state. Still further, the first additional forward gear has high gear mesh efficiency.

According to an example embodiment, the method may comprise the step of positioning the first, second and third connecting mechanisms in an engaged state when engaging a second additional forward gear having a gear ratio lower than the gear ratio of the ninth forward gear.

Hereby, an additional gear is provided which can increase the vehicle speed even further in, comparison to the ninth forward gear. An advantage is thus that the vehicle may be able to drive at a faster speed in situations where this is desirable.

According to an example embodiment, the method may comprise the step of positioning the first, second and fourth connecting mechanisms in an engaged state when engaging a first additional reverse gear having a gear ratio between the second and the third reverse gears.

According to an example embodiment, the method may comprise the step of positioning the second locking mechanism, and the first and the fourth connecting mechanisms in an engaged state when engaging a second additional reverse gear having a gear ratio between the second and the third reverse gears.

According to an example embodiment, the method may comprise the step of positioning the second locking mechanism, and the first and the second connecting mechanisms in an engaged state when engaging a third additional reverse gear having a gear ratio lower than the gear ratio of the third reverse gear in terms of absolute values.

Hereby, three additional reverse gears are obtained. It has been realized that the third reverse gear can be removed when providing the three additional reverse gears which, thus provides five reverse gears for the transmission arrangement. These five reverse gears have beneficial steps and all one-step gear shifts as well as all two-step gear shifts are performed by only shifting one of the connecting and locking mechanisms from an engaged state to a disengaged state, and only shifting one of the connecting and locking mechanisms from a disengaged state to an engaged state.

Also, the third additional reverse gear enables for a further increased reverse vehicle speed. Hence, the vehicle is able to reverse at a faster speed if desired.

It should be readily understood that the above defined example embodiments of forward and reverse gears may be combined in any suitable combination.

Further effects and features of the second aspect of the present invention are largely analogous to those described above in relation to the first aspect of the present invention.

According to a third aspect of the present invention there is provided a control unit configured to control a transmission arrangement, the transmission arrangement comprising a first, a second, a third, and a fourth planetary gear set comprising a sun gear, a planet carrier and, a ring gear, respectively, wherein said transmission arrangement further comprises a transmission housing, an input shaft and n output shaft, wherein the ring gear of the first planetary gear set being operatively connected to the input shaft; the sun gear of the first planetary gear set being operatively connected to the sun gear of the second planetary gear set; the planet carrier of the second planetary gear set being operatively connected to the ring gear of the third planetary gear set; the planet carrier of the third planetary gear set being operatively connected to the transmission housing the sun gear of the third planetary gear set being operatively connected to the sun gear of the fourth planetary gear set; the planet carrier of the fourth planetary gear set being operatively connected to the output shaft, wherein the transmission arrangement further comprises a first connecting mechanism for selectively connecting the ring gear of the second planetary gear set to the ring gear of the first planetary gear set and to the input shaft; a second connecting mechanism for selectively connecting the planet carrier of the first planetary gear set to the output shaft and to the planet carrier of the fourth planetary gear set; a third connecting mechanism for selectively connecting the ring gear of the fourth planetary gear set to the sun gear of the first planetary gear set and to the sun gear of the second planetary gear set; a fourth connecting mechanism for selectively connecting the planet carrier of the first planetary gear set to the ring gear of the fourth planetary gear set; a first locking mechanism for selectively locking the ring gear of the fourth planetary gear set to the transmission housing; a second locking mechanism for selectively locking the sun gear of the third planetary gear set and the sun gear of the fourth planetary gear set to the transmission housing; and a third locking mechanism for selectively locking the ring gear of the second planetary gear set to the transmission housing, wherein for at least one of the gears of the transmission arrangement, the control unit is configured to position three of the locking and connecting mechanisms in an engaged state; and position four of the locking and connecting mechanisms in a disengaged state.

Effects and features of the third aspect of the present invention are largely analogous to those described above in relation to the first and second aspects of the present invention.

According to a fourth aspect of the present invention there is provided a vehicle comprising a prime mover and a gearbox, wherein the gearbox comprises a transmission arrangement according to any one of the embodiments described above in relation to the first aspect of the present invention.

Effects and features of the fourth aspect of the present invention are largely analogous to those described above in relation to the first, second and third aspects of the present invention.

Further features of, and advantages with, the present invention will become apparent when studying the appended claims and the following description. The skilled person realize that different features of the present invention may be combined to create embodiments other than those described in the following, without departing from the scope of the present invention.

Definitions

The relationship between the rotational speeds of the different members in a planetary gear set is defined according to the following:

$$\frac{\omega_S - \omega_P}{\omega_R - \omega_P} = R \quad \text{(Eq. 1)}$$

wherein

ω_S is the speed of rotation of the sun gear;

ω_P is the speed of rotation of the planet carrier;

ω_R is the speed of rotation of the ring gear; and

R is the stationary gear ratio of the planetary gear set.

As used herein, the expression "stationary gear ratio" R for a planetary war set is defined as the ratio of the speed of rotation of the sun gear to the speed of rotation of the ring gear in a situation in which the planet carrier is stationary, i.e.:

$$R = -\frac{z_R}{z_S} \text{ for single planet gear wheels} \quad \text{(Eq. 2)}$$

and

$$R = +\frac{z_R}{z_S} \text{ for double planet gear wheels} \quad \text{(Eq. 3)}$$

wherein

z_R is the number of teeth of the ring gear; and

Z_S is the number of teeth of the sun gear.

In a similar manner, the expression "ratio" for a transmission arrangement should be understood to relate to the number of revolutions of the input shaft of the transmission arrangement divided by the number of revolutions of the output shaft of the transmission arrangement. Furthermore, the expression "step" should be understood to mean the quotient achieved when the ratio of a gear is divided by the ratio of an adjacent gear of a transmission arrangement.

BRIEF DESCRIPTION OF THE DRAWINGS

The above, as well as additional features and advantages of the present invention, will be better understood through the following illustrative and non-limiting detailed description of exemplary embodiments of the present invention, wherein:

FIG. **1** is a lateral side view illustrating a working machine in the form of an articulated hauler; and

FIG. **2** schematically illustrates a transmission arrangement according to an example embodiment of the present invention.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS OF THE INVENTION

The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which exemplary embodiments of the invention are shown. The invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided for thoroughness and completeness. Like reference character refer to like elements throughout the description.

FIG. **1** is a side view of a working machine **201** in the form of an articulated hauler having a tractor unit **202** with a cab **203** for a driver and a trailer unit **204** with a platform having a dump body **205**, here in the form of a container, arranged thereon, for receiving load. The dump body **205** is preferably pivotally connected to the rear section and tiltable by means of a pair of tilting cylinders **206**, for example hydraulic cylinders. The tractor unit **202** has a frame **207** and a pair of wheels **208** suspended from the frame **207**. The trailer unit **204** has a frame **209** and two pair of wheels **210**, **211** suspended from the frame **209**.

The working machine is frame-steered, i.e. there is a joint arrangement **212** connecting the tractor unit **202** and the trailer unit **204** of the working machine **201**. The tractor unit **202** and the trailer unit **204** are pivotally connected to each other for pivoting around a substantially vertical pivot axis **213**.

The working machine preferably comprises a hydraulic system having two hydraulic cylinders **214**, steering cylinders, arranged on opposite sides of the working machine for turning the working machine by means of relative movement of the tractor unit **202** and the trailer unit **204**. The hydraulic cylinders can, however, be replaced by any other linear actuator for steering the machine, such as an electromechanical linear actuator,

Furthermore, the articulated hauler comprises a prime mover **216**, here illustrated as an internal combustion engine, and a gearbox **218** having a transmission arrangement according to the example embodiment described below in relation to FIG. **2**. Still further, the articulated hauler also comprises a control unit **600** connected to the gearbox for controlling the below described transmission arrangement. The control unit **600** may be, or form part of, already existing control Units for controlling a gearbox.

Now, with reference to FIG. **2**, an example embodiment of a transmission arrangement **100** according to the present invention is illustrated. The transmission arrangement **100** comprises a first planetary gear set **102** comprising a sun gear **102**S, a planet carrier **102**P and a ring gear **102**R, a second planetary gear set **104** comprising a sun gear **104**S, a planet carrier **104**P and a ring gear **104**R, a third planetary gear set **106** comprising a sun gear **106**S, a planet carrier **106**P and a ring gear **106**R, and a fourth planetary gear set **108** comprising a sun gear **108**S, a planet carrier **108**P and a ring gear **108**R. The transmission arrangement **100** further comprises an input shaft **136** for receiving a rotary motion/torque from the prime mover **216** of the vehicle **201** and an output shaft **112** for providing a rotary motion/torque to the driven wheels of the vehicle **201**.

The different members of the planetary gear sets **102**, **104**, **106**, **108** of the transmission arrangement **100**, i.e. the sun gear, the planet carrier and the ring gear, are in the example embodiment depicted in FIG. **2** configured according to the following. It should be readily understood that the different members described below are connected to each other, either directly, i.e. operatively connected, or via a connecting mechanism, i.e. selectively connectable. The members can be operatively connected to each other by means of e.g. a connector element. Such connector element can be e.g. a solid shaft, a hollow shaft or a drum, or other suitable element for connecting two members to each other, which elements are known to the person skilled in the art. Hence, no explicit explanation is given below in regards to the means connecting the members to each other.

The input shall **136** of the transmission arrangement **100** is operatively connected to the ring gear **102**R of the first planetary gear set **102**, i.e. the input shaft **136** is at all times directly connected to the ring gear **102**R of the first planetary gear set **102**. The input shaft **136** and the ring gear **102**R of the first planetary gear set **102** are further selectively connectable to the ring gear **104**R of the second planetary gear set **104** by means of a first connecting mechanism **120**. Further, the sun gear **102**S of the first planetary gear set **102** is operatively connected to the sun gear **104**S of the second planetary gear set **104**. Also, the sun gear **102**S of the first planetary gear set **102** and the sun gear **104**S of the second planetary gear set **104** are selectively connectable to the ring gear **108**R of the fourth planetary gear set **108** by means of a third connecting mechanism **124**.

Furthermore, the planet carrier **102**P of the first planetary gear set **102** is selectively connectable to the output shaft **112** by means of a second connecting mechanism **122**. The planet carrier **102**P of the first planetary gear set **102** is also selectively connectable to the ring gear **108**R of the fourth planetary gear set **108** by means of a fourth connecting mechanism **126**.

The planet carrier **104**P of the second planetary gear set **104** is operatively connected to the ring gear **106**R of the third planetary gear set **106**. Further, the ring gear **104**R of the second planetary gear set **104** is selectively connectable to the transmission housing **160** by means of a third locking mechanism **132**. Hence, the third locking mechanism **132**, when being engaged, initially reduces the rotational speed of the ring gear **104**R of the second planetary gear set **104**, and thereafter locks the ring gear **104**R of the second planetary gear set **104** to the transmission housing **160**.

The sun gear **106**S of the third planetary gear set **106** is operatively connected to the sun gear **108**S of the fourth planetary gear set **108**. Further, the planet carrier **106**P of the third planetary gear set **106** is operatively connected to the transmission housing **160**. Hence, the planet carrier **106**P of the third planetary gear set **106** is at all times prevented from rotating. Furthermore, the sun gear **106**S of the third planetary gear set **106** and the sun gear **108**S of the fourth planetary gear set **108** are selectively connectable to the planet carrier **106**P of the third planetary gear set **106** by means of a second locking mechanism **130**. Hereby, when engaging the second locking mechanism **130**, the sun gear **106**S of the third planetary gear set **106** and the sun gear **108**S of the fourth planetary gear set **108** are prevented from rotating since the planet carrier **106**P of the third planetary gear set **106** is operatively connected to the transmission housing **160**.

The planet carrier **108**P of the fourth planetary gear set **108** is operatively connected to the output shaft **112** of the transmission arrangement **100**. Further, the ring gear **108**R of the fourth planetary gear set **108** is selectively connectable to the planet carrier **106**P of the third planetary gear set **106** by means of a first locking mechanism **128**. Hereby, when engaging the first locking mechanism **128**, the ring gear **108**R of the fourth planetary gear set **108** is prevented from rotating since the planet carder **106**P of the third planetary gear set **106** is operatively connected to the transmission housing **160**.

The above described connecting mechanisms may be respective clutch arrangements which are either wet clutches or dry clutches. The locking mechanisms may be constituted by brake arrangements such as e.g. wet or dry brake arrangements.

According to the example embodiment depicted in FIG. **2**, the stationary gear ratio of each one of the first **102**, second **104**, third **106**, and fourth **108** planetary gear sets are negative. According to a non-limiting example, the stationary gear ratio for each of the planetary gear sets may be as described below in Table 1.

TABLE 1

Exemplary stationary gear ratios for the embodiment depicted in FIG. 2.

First planetary gear set (102)	Second planetary gear set (104)	Third planetary gear set (106)	Fourth planetary gear set (108)
−1.700	−3.275	−2.075	−2.575

The above described example embodiment depicted in FIG. **2** is adapted to assume the gears as presented in Table 2 below. As indicated, the transmission arrangement depicted in FIG. **2** assumes nine forward gears and three reverse gears. In Table 2 below, the locking mechanisms are denoted simply as "Brakes" while the connecting mechanisms are denoted simply as "Clutches". A cell marked with a dot indicates an engaged state and a blank cell indicates a disengaged state. Furthermore, Table 2 also indicates non-limiting examples of the gear ratios and steps obtainable by the transmission arrangement for the various gears. The gear ratios and steps presented in Table 2 are derived from the exemplary stationary gear ratios presented in Table 1 above.

TABLE 2

Shift diagram, gear ratios and steps for the different gears.

	Brakes			Clutches					
Gear	128	130	132	120	122	124	126	Ratio	Step
1	●		●		●			5.92	1.37
2	●		●				●	4.33	1.55
3			●		●		●	2.80	1.27
4		●	●				●	2.21	1.29
5			●			●	●	1.71	1.23

TABLE 2-continued

Shift diagram, gear ratios and steps for the different gears.

	Brakes			Clutches					
Gear	128	130	132	120	122	124	126	Ratio	Step
6		●				●	●	1.39	1.39
7					●	●	●	1.00	1.30
8		●			●	●		0.77	1.33
9			●		●	●		0.58	
R1	●			●	●			−6.39	1.37
R2	●			●			●	−4.68	2.08
R3	●			●		●		−2.25	

As depicted in Table 2 above, the transmission arrangement in FIG. **2** comprises nine forward gears and three reverse gears (indicated with an R). The switching of gears can preferably be executed by one-step gear shifts or with two-step gear shifts. One-step gear shift should be understood to mean that a gear shift is executed from one gear to the next coming consecutive gear, for example, gear shift from the first gear to the second gear, from the second gear to the third gear, from the third gear to the second gear, etc. Two-step gear shift should be understood to mean that a gear shift is executed to exclude a next coming consecutive gear, for example, gear shift from the first gear to the third gear, from the second gear to the fourth gear, from the third gear to the first gear, etc.

As can be seen from Table 2, one-step gear shifting includes only single shifts of the connecting mechanisms and the locking mechanisms, i.e. when executing one-step gear shifts, only one of the connecting mechanisms/locking mechanisms is shifted from an engaged state to a disengaged state, and only one of the connecting mechanisms/locking mechanisms is shifted from a disengaged state to an engaged state. As an example, when shifting from the first forward gear to the second forward gear, it is only the second connecting mechanism **122** that is changed from an engaged state to a disengaged state, and only the fourth connecting mechanism **126** that is changed from a disengaged state to an engaged state.

Furthermore, and as is depicted in Table 2, also two-step gear shifting only includes single shifts of the connecting mechanisms/locking mechanisms, i.e. when executing two-step gear shifts, only one of the connecting mechanisms/locking mechanisms is shifted from an engaged state to a disengaged state, and only one of the connecting mechanisms/locking mechanisms is shifted from a disengaged state to an engaged state. As an example, when shifting from the fourth forward gear to the sixth forward gear, it is only the third locking mechanism **132** that is changed from an engaged state to a disengaged state, and only the third connecting mechanism **124** that is changed from a disengaged state to an engaged state.

An advantage of the transmission arrangement is hence that the shiftability is improved since a reduced number of connecting mechanisms/locking mechanisms need activation/deactivation during gear shifting. In detail, during both one-step gear shifting and two-step gear shifting, which are the most common gear shift sequences, only single shifts occur.

Moreover, with the above described example embodiment of the transmission arrangement **100**, further additional gears are obtainable. Table 3 below illustrates additional gears which are possible to obtain by the transmission arrangement **100** depicted and described above.

In Table 3, gear 0.5* is an additional gear with a gear ratio higher than the gear ratio of the first forward gear. Also, forward gears 5.5* and 5.5** are additional gears, both having a gear ratio between the gear ratios of the fifth and sixth forward gears. In the following, gear 5.5** is referred to as the first additional forward gear. Further, forward gear 10* is a second additional forward gear having a gear ratio lower than the gear ratio of the ninth forward gear, which makes the second additional forward gear a faster gear compared to the ninth forward gear.

Furthermore, gears R2.5* and R2.9* are respective first and second additional reverse gear each having a gear ratio between the gear ratios of the second and third reverse gears. Still further, gears R4* and R5* are respective third and fourth additional reverse gears each having gear ratios lower than the gear ratio of the third reverse gear in terms of absolute values. Hence, the third and fourth additional reverse gears are faster than the third reverse gear, wherein the fourth additional reverse gear is faster than the third additional reverse gear.

TABLE 3

Shift diagram, gear ratios and steps for the different gears.

	Brakes			Clutches					
Gear	128	130	132	120	122	124	126	Ratio	Step
0.5*				●		●	●	7.15	1.21
1	●		●		●			5.92	1.37
2	●		●				●	4.33	1.55
3			●		●		●	2.80	1.27
4		●	●				●	2.21	1.29
5			●			●	●	1.71	1.08
5.5*	●				●	●		1.59	1.00
5.5**		●	●		●			1.59	1.14
6		●				●	●	1.39	1.39
7					●	●	●	1.00	1.30
8		●			●	●		0.77	1.33
9			●		●	●		0.58	1.45
10*				●	●	●		0.40	
R1	●			●	●			−6.39	1.37
R2	●			●			●	−4.68	1.55
R2.5*				●	●		●	−3.02	1.27
R2.9*		●		●			●	−2.38	1.06
R3	●			●		●		−2.25	1.31
R4*		●		●	●			−1.71	4.04
R5*		●		●		●		−0.42	

Hence, with the transmission arrangement depicted and described in relation to FIG. **2**, a plurality of additional gears can be achieved. A further advantage is thus that the transmission arrangement according to the present invention has an increased variability when choosing the gears to be used. Thus a plurality of alternatives is possible when designing gear shifting of the transmission arrangement.

It is to be understood that the present invention is not limited to the embodiments described above and illustrated in the drawings; rather, the skilled person will recognize that many changes and modifications may be made within the scope of the appended claims. For example, although the present invention has mainly been described in relation to an articulated hauler, the invention should be understood to be equally applicable for any type of vehicle.

The invention claimed is:

1. A transmission arrangement for a vehicle, the transmission arrangement comprising a first, a second, a third, and a fourth planetary gear set comprising a sun gear, a planet carrier and a ring gear, respectively, wherein the transmission arrangement further comprises a transmission housing, an input shaft and an output shaft, wherein the ring gear of the first planetary gear set and the input shaft are operatively connected to each other;

the sun gear of the first planetary gear set and the sun gear of the second planetary gear set are operatively connected to each other;

the planet carrier of the second planetary gear set and the ring gear of the third planetary gear set are operatively connected to each other;

the planet carrier of the third planetary gear set is operatively connected to the transmission housing;

the sun gear of the third planetary gear set and the sun gear of the fourth planetary gear set are operatively connected to each other; and

the planet carrier of the fourth planetary gear set and the output shaft are operatively connected to each other.

2. The transmission arrangement according to claim **1**, wherein the transmission arrangement comprises a first connecting mechanism for selectively connecting the ring gear of the second planetary gear set to the ring gear of the first planetary gear set and to the input shaft.

3. The transmission arrangement according to claim **1**, wherein the transmission arrangement comprises a second connecting mechanism for selectively planet carrier of the first planetary gear set to the output shaft and to the planet carrier of the fourth planetary gear set.

4. The transmission arrangement according to claim **1**, wherein the transmission arrangement comprises a third connecting mechanism for selectively connecting the ring gear of the fourth planetary gear set to the sun gear of the first planetary gear set and to the sun gear of the second planetary gear set.

5. The transmission arrangement according to claim **1**, wherein the transmission arrangement comprises a fourth connecting mechanism selectively connecting the planet carrier of the first planetary gear set to the ring gear of the fourth planetary gear set.

6. The transmission arrangement according to claim **1**, wherein the transmission arrangement comprises a first locking mechanism for selectively locking the ring gear of the fourth planetary gear set to the transmission housing.

7. The transmission arrangement according to claim **6**, wherein the ring gear of the fourth planetary gear set is selectively connectable to the transmission housing via the planet carrier of the third planetary gear set.

8. The transmission arrangement according to claim **1**, wherein the transmission arrangement comprises a second locking mechanism for selectively locking the sun gear of the third planetary gear set and the sun gear of the fourth planetary gear set to the transmission housing.

9. The transmission arrangement according to claim **8**, wherein the sun gear of the third planetary gear set and the sun gear of the fourth planetary gear set are selectively connectable to the transmission housing via the planet carrier of the third planetary gear set.

10. The transmission arrangement according to claim **1**, wherein the transmission arrangement comprises a third locking mechanism for selectively locking the ring gear of the second planetary gear set to the transmission housing.

11. The transmission arrangement according to claim **1**, wherein the stationary gear ratio of each one of the first, second, third and fourth planetary gear sets are negative.

12. A vehicle comprising a prime mover and a gearbox, wherein the gearbox comprises a transmission arrangement according to claim **1**.

13. A method for controlling a transmission arrangement, the transmission arrangement comprising a first, a second, a third, and a fourth planetary gear set comprising a sun gear, a planet carrier and a ring gear, respectively, wherein the transmission arrangement further comprises a transmission housing, an input shaft and an output shaft, whereby:

the ring gear of the first planetary gear set being operatively connected to the input shaft;

the sun gear of the first planetary gear set being operatively connected to the sun gear of the second planetary gear set;

the planet carrier of the second planetary gear set being operatively connected to the ring gear (**106**R) of the third planetary gear set;

the planet carrier of the third planetary gear set being operatively connected to the transmission housing;

the sun gear of the third planetary gear set being operatively connected to the sun gear of the fourth planetary gear set;

the planet carrier of the fourth planetary gear set being operatively connected to the output shaft, wherein the transmission arrangement further comprises:

a first connecting mechanism for selectively connecting the ring gear of the second planetary gear set to the ring gear of the first planetary gear set and to the input shaft;

a second connecting mechanism for selectively connecting the planet carrier of the first planetary gear set to the output shaft and to the planet carrier of the fourth planetary gear set;

a third connecting mechanism for selectively connecting the ring gear of the fourth planetary gear set to the sun gear of the first planetary gear set and to the sun gear of the second planetary gear set;

a fourth connecting mechanism for selectively connecting the planet carrier of the first planetary gear set to the ring gear of the fourth planetary gear set;

a first locking mechanism for selectively locking the ring gear of the fourth planetary gear set to the transmission housing;

a second locking mechanism for selectively locking the sun gear of the third planetary gear set and the sun gear of the fourth planetary gear set to the transmission housing; and

a third locking mechanism for selectively locking the ring gear of the second planetary gear set to the transmission housing, wherein for at least one of the gears of the transmission arrangement, the method comprises the steps of:

positioning three of the locking and connecting mechanisms in an engaged state; and

positioning four of the locking and connecting mechanisms in a disengaged state.

14. A control unit configured to control a transmission arrangement, the transmission arrangement comprising a first, a second, a third, and a fourth planetary gear set comprising a sun gear, a planet carrier and a ring gear, respectively, wherein the transmission arrangement further comprises a transmission housing, an input shaft and an output shaft, wherein:

the ring gear of the first planetary gear set being operatively connected to the input shaft;

the sun gear of the first planetary gear set being operatively connected to the sun gear of the second planetary gear set;

the planet carrier of the second planetary gear set being operatively connected to the ring gear (**106**R) of the third planetary gear set;

the planet carrier of the third planetary gear set being operatively connected to the transmission housing;

the sun gear of the third planetary gear set being operatively connected to the sun gear of the fourth planetary gear set;

the planet carrier of the fourth planetary gear set being operatively connected to the output shaft, wherein the transmission arrangement further comprises:

a first connecting mechanism for selectively connecting the ring gear of the second planetary gear set to the ring gear of the first planetary gear set and to the input shaft;

a second connecting mechanism for selectively connecting the planet carrier of the first planetary gear set to the output shaft and to the planet carrier of the fourth planetary gear set;

a third connecting mechanism for selectively connecting the ring gear of the fourth planetary gear set to the sun gear of the first planetary gear set and to the sun gear of the second planetary gear set;

a fourth connecting mechanism for selectively connecting the planet carrier of the first planetary gear set to the ring gear of the fourth planetary gear set;

a first locking mechanism for selectively locking the ring gear of the fourth planetary gear set to the transmission housing;

a second locking mechanism for selectively locking the sun gear of the third planetary gear set and the sun gear of the fourth planetary gear set to the transmission housing; and

a third locking mechanism for selectively locking the ring gear of the second planetary gear set to the transmission housing, wherein for at least one of the gears of the transmission arrangement, the control unit (**600**) is configured to:

position three of the locking and connecting mechanisms in an engaged state; and

position four of the locking and connecting mechanisms in a disengaged state.

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